Original Article

BEHAVIOR OF BEAM AND WALL OUTRIGGER IN HIGH -RISE

BUILDING AND THEIR COMPARISON

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ABSTRACT

Tall buildings need a lateral load resisting system to resist the lateral loads induced by wind or earthquake forces. One of the most efficient systems is outrigger. Outriggers are structural systems that support building against lateral loads. Outriggers are rigid horizontal structures designed to improve building overturning stiffness and strength. This paper provides an overview of outrigger systems and studying the comparison of beam and wall outrigger. A three structures of 30 story building was investigated in this research study. Response spectrum analysis was conducted and the behavior of the buildings was determined considering response parameters such as lateral displacement and story drift. It has been shown from this study that the structure with wall outrigger is more efficient than the structure with beam outrigger. One of the most effective techniques is the use of outrigger in structures that can astutely solve the above issues in high-rise constructions.

KEYWORDS: High Rise Building, Lateral Load, Beam Outriggers, Wall Outriggers, ETABS

INTRODUCTION

High Rise Building

It is difficult to distinguish the characteristics of a building which categorize it as high the outward appearance of highness is a relative matter. In Europe, a 20 –story building in a city may be called a high rise, but the citizens of small town may point to their skyscraper of six floors. In large cities, which are comprised of a vast number of high rise buildings, a structure must pierce the sky a round 70-100 story if it is to appear tall in comparison with its immediate neighbor.

Definition of High Rise Building

High rise building cannot be defined in specific terms related to height or number of floors. From the structural design point of view, it is simpler to consider the building as high when its structural analyses and design are in some way affected by the lateral loads particularly the drift caused by such loads.

Classification of High Rise Building

Structural systems of tall buildings can be divided into two broad categories: *interior structures and exterior structures*. Tables 1 and 2 summarize the details of the systems in each category. In addition, Figure 1 and 2 show the concept of each system diagrammatically.
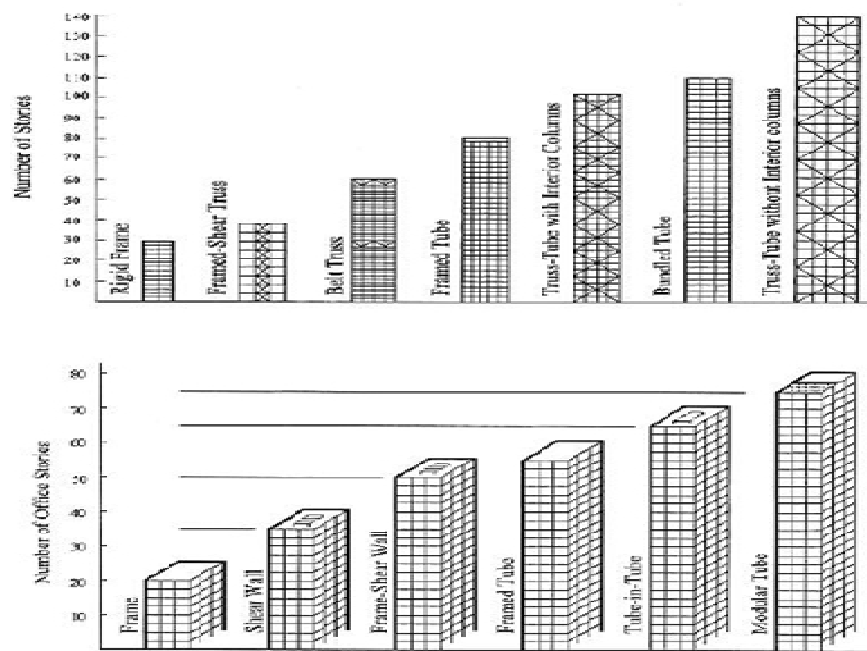
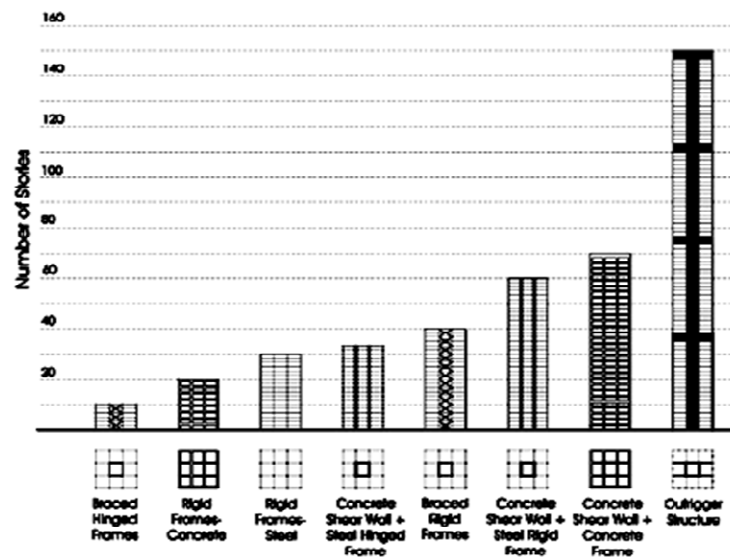**Figure 1: Classification of Tall Building Structural Systems by FazlurKhan (above: Steel; below: Concrete)**

Figure 2: Interior Structures

Table 1: Interior Structures

Category	Sub-Category	Material/Configuration	Efficient Height Limit	Advantages	Disadvantages
Rigid Frames	——	Concrete	20	Provide flexibility in floor planning. Easily moldable	Expensive form work. Slow construction.
Braced Hinged Frames	——	Steel Shear Trusses + Steel Hinged Frames	10	Efficiently resist lateral loads by axial forces in the shear truss members. Allows shallower beams compared with the rigid frames without diagonals.	Interior planning limitations due to diagonals in the shear trusses. Expensive diagonal connections.

Table 1: Contd.,					
Shear Wall/ Hinged Frames	——	Concrete Shear wall + Steel Hinged Frame	35	Effectively resists lateral shear by concrete shear walls.	Interior planning limitations due to shear trusses.
Shear Wall (or Shear Truss – Frame Interaction System	Shear wall / Rigid Frame	Concrete Shear wall + Steel Rigid frame	60	Effectively resists lateral loads by producing shear wall – frame interacting system.	Interior planning limitations due to shear walls.
		Concrete Shear wall + concrete frame	70	Effectively resists lateral loads by shear wall – frame interacting system.	Interior planning limitations due to shear walls.
Outrigger Structures	——	Shear Cores(Steel Trusses or Concrete shear walls) + Outriggers (Steel Trusses or Concrete walls) +Belt Trusses) +Steel or Concrete Composite (Super) Columns	150	Effectively resists bending by exterior columns connected to outriggers extended from the core.	Outrigger structure does not add shear resistance.

Table 2: Exterior Structures

Category	Sub-Category	Material/ Configuration	Efficient Height Limit	Advantages	Disadvantages
Tube	Framed Tube	Concrete	60	Effectively resists lateral loads by locating lateral systems at the building perimeter.	Shear lag hinders true tubular behavior. Narrow column spacing obstructs the view.
	Braced Tube	Concrete	100	Effectively resists lateral shear by axial forces in the diagonal members. Wider column spacing possible compared with framed tubes. Reduced shear lag.	Bracing obstructs the view.
	Bundled Tube	Concrete	110	Reduced shear lag.	Interior planning limitations due to the bundled tube configuration.
	Tube in Tube	Ext. Frame tube(Steel or Concrete) +Int. Core Tube(Steel or Concrete)	80	Effectively resists lateral loads by producing interior shear core – exterior framed tube interacting system.	Interior planning limitations due to shear core.
Diagrid	——	Concrete	60	Effectively resists lateral shear by axial forces in the diagonal members.	Expensive form work. Slow construction.
Super frames	——	Concrete	100	Could produce super tall buildings.	Building form depends to a great degree on the structural system.

Outrigger and Belt Wall System

The structural arrangement for this system consists of a main concrete core connected to exterior columns by relatively stiff horizontal members such as a one or two-story deep walls commonly referred to as outriggers. The basic structural response of the system is quite simple. When subjected to lateral loads. The external moment is now resisted not by bending of the core alone, but also by the axial tension and compression of the exterior columns connected to the outriggers. As a result, the effective depth of the structure for resisting bending is increased when the core flexes as a vertical cantilever, by the development of tension in the windward columns, and by compression in the leeward columns. This is achieved by tying the exterior columns with a one- or two-story deep wall commonly referred to as a "belt wall," around the building. To achieve efficiency, the outriggers and belt walls are made one—and often two—stories deep with door-size openings in the outriggers for circulation. It is also possible to use vierendeel frames extending through several floors to act as outriggers, as shown in. Yet another option is to use girders, such as haunch girders, at each floor. It should be noted that whereas the outrigger is effective in increasing the structure's flexural stiffness, it does not increase resistance to shear, which must be carried only by the core. To understand the behavior of an outrigger system, consider a building stiffened by a story-high outrigger wall at top. Because the outrigger is at the top, the system is often referred to as a cap or hat wall system. The tie-down action of the cap wall generates a restoring couple at the building top, resulting in the occurrence of a point of contra flexure some distance from the top. The resulting reversal in curvature reduces the bending moment in the core and hence the Building drift. Of the outrigger wall. This idealization is not necessary in developing the theory, but keeps the explanation simple. Therefore, the cap wall may be conceptualized as a restraining spring located at the top of the shear core.

Optimum Locations of Two Outriggers

In the preceding conceptual analyses, only one compatibility equation was necessary because the one-outrigger structure is once-redundant. On the other hand, a two-outrigger structure is twice redundant, requiring a solution of two compatibility equations. To seek a solution to the problem, we proceed as before assuming the sectional areas of the exterior columns and the moment of inertia of the core decrease linearly up the height. A trapezoidal distribution is assumed, as before, for the lateral load. Schematics of conceptual analytical model and behavior of the structural system are shown in Figures 3. The method of analysis for calculating the deflections at the top is similar to that used for the single outrigger. The moments at the outrigger locations are chosen as the unknown arbitrary constants M1 and M2, see Figure 4.

The structure is then rendered statically determinate by removing the rotational restraints at the outrigger locations. Next, the compatibility equations for the rotations at the truss locations are set up and solved simultaneously to obtain the values to M1 and M2. The final deflection at the top is obtained by a superposition of the deflection due to the external load and a counteracting deflection due to the moments M1 and M2. The resulting deflections are summarized in Figure 5.
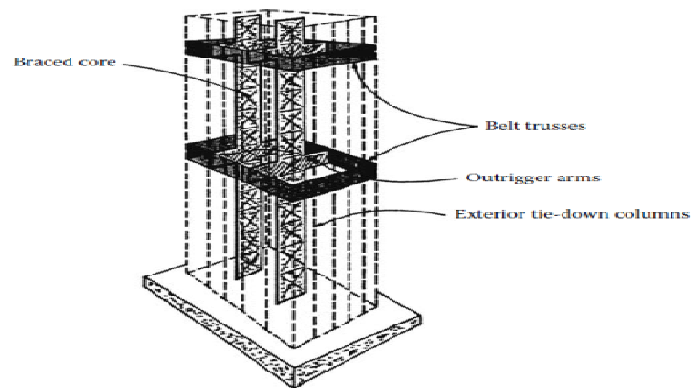
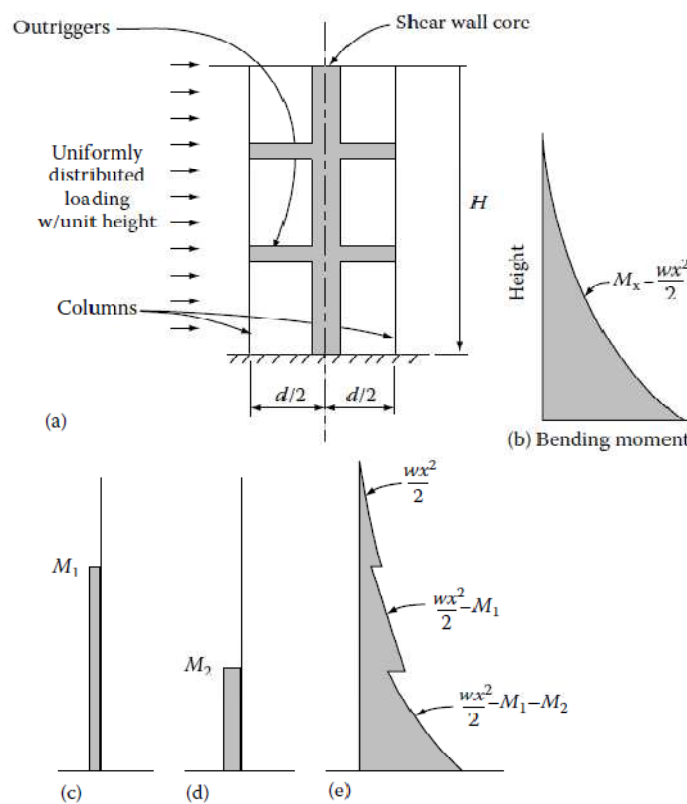**Figure 3: Building with Outrigger and Bet Truss at Two Location**

Figure 4: Method of Analyses of Two Outrigger System

Optimum Locations of Outrigger Trusses

It's been recommended that the optimum level of the outriggers for minimizing the drift for a single outrigger is at approximately mid-height (Figure 6). A two outrigger system would have one placed at 1/3 and the other placed at 2/3 of the Building height [30]. For a three-outrigger system, they should be at the 1/4, 1/2, and 3/4 heights, and so on. Therefore, for the optimum performance of an n-outrigger structure, the outriggers should be placed at 1/n + 1, 2/n + 1, 3/n + 1, 4/n + 1… n/n + 1 height locations.

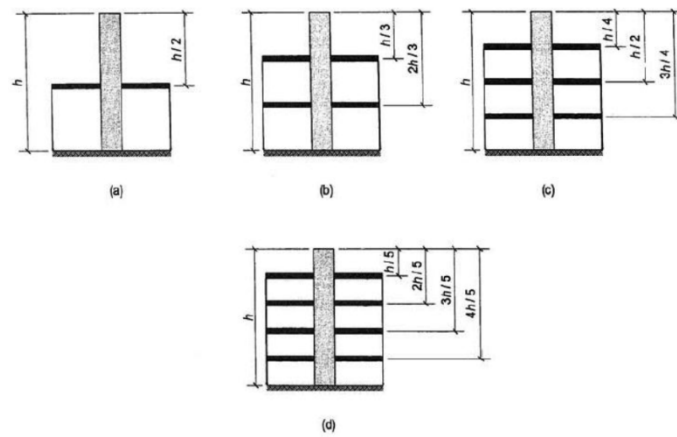**Figure 5: Optimum Locations of Outriggers: (a) Single Outrigger;**
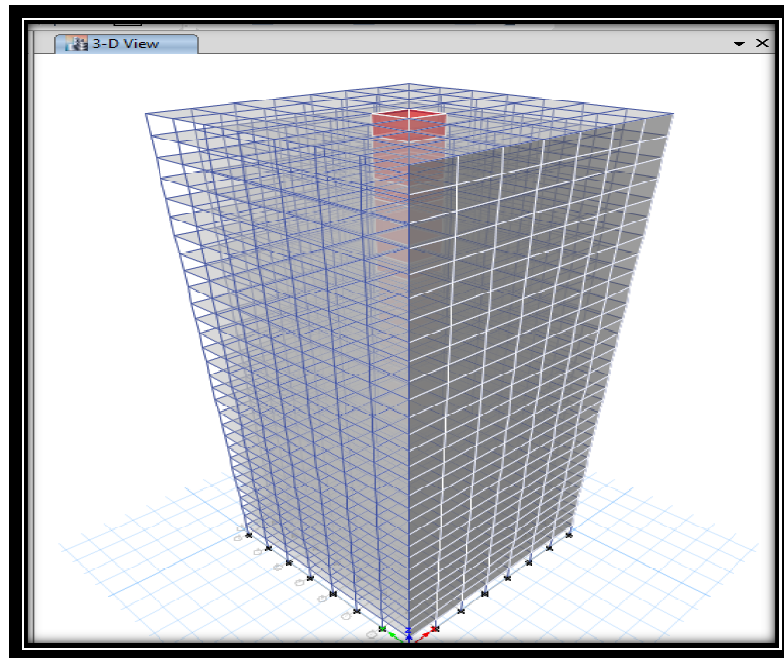**(b) Two Outriggers; (c) Three Outriggers; (d) Four Outriggers29**

Figure 6: D of the Mode

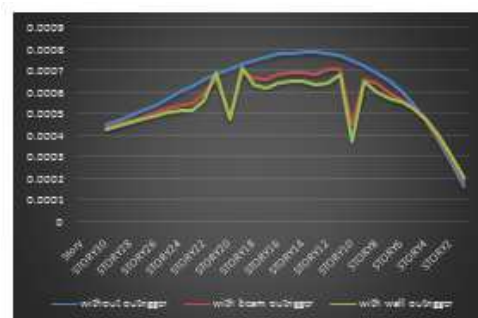## GRAPHS

Comparison of Story Drift for

Figure 7: Load Combination 0.9DL-1.5EQX
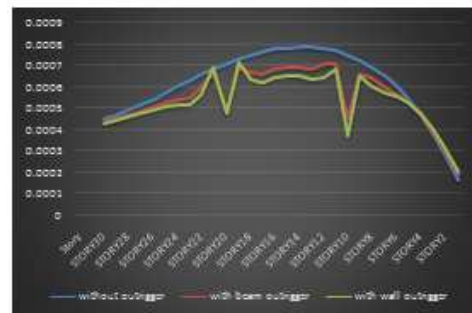
Comparison of Shear Force for C1

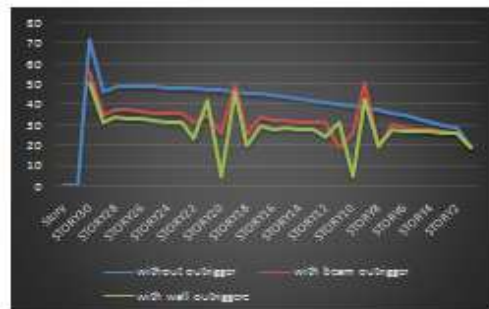**Figure 8: Load combination 0.9DL-1.5EQX**

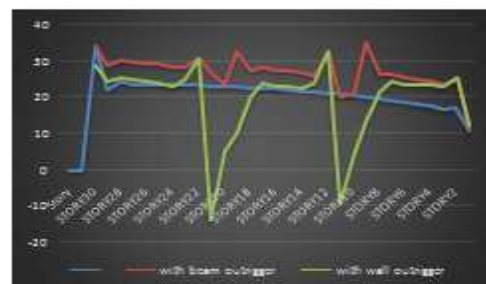**Figure 9: Load Combination 1.2(DL+LL+EQX)**

Figure 10: Load Combination (0.9DL-1.5EQX)

Comparison of Torsion for C1

Figure 11: Load combination 1.2(DL+LL+EQX)

Figure 12: Load Combination (0.9DL-1.5EQX)

Comparison of Bending Moment for C1

- Without outrigger.

- With beam outrigger.

- With wall outrigger.

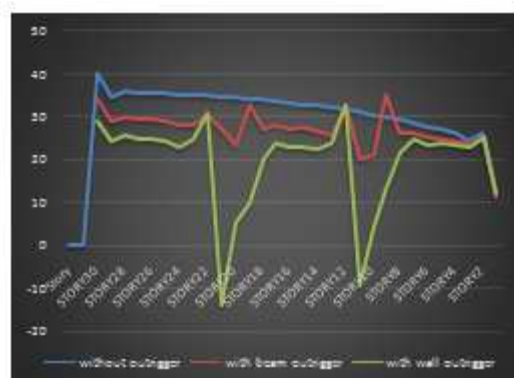**Figure 13: Load Combination 1.2(DL+LL+EQX)**

Figure 14: Load Combination (0.9DL-1.5EQX)

CONCLUSIONS

This paper has presented a comparison of beam and wall outrigger structural systems for high rise buildings. The design of tall structures is controlled by three governing factors, strength, drift, maximum lateral displacement. The

outrigger concept is in wide spread use today in the design of tall buildings. In this concept outrigger beam or wall should connect lateral load resisting core to the columns at the exterior of the building. The core consist of shear walls. The use of beam or wall outrigger system in high-rise buildings increase the stiffness and makes the structural form efficient under lateral load.

The analysis is carried out for study of rigid core and floor rigidity of 30 story building for the following structures:-

Structure 1: Building frame without outrigger.

Structure 2: Building frame with beam outrigger and belt truss.

Structure 3: Building frame with wall outrigger and belt wall.

Both beam and wall outrigger are provided at the first third and second third of the structure height. According to Bungale S. Taranath theory, the outriggers should be placed at $(1/n + 1)$, $(2/n + 1)$, $(3/n + 1)$, $(4/n + 1)$… $(n/n + 1)$ height locations. The optimum location for a two-outrigger structure is at one-third and two-third heights.

From the analysis of the Data the following conclusions have been made:-

- The use of outrigger system in high-rise buildings increase the stiffness and makes the structural form efficient under lateral load.

- Drift in all of the systems is less than the prescribed limit of H/500.

- Due to presence of the wall outrigger and belt wall in Structure 3, it is Stiffer Structure when compared to structure with beam outrigger and belt truss. This is reflected in reduction of story displacement and story drift values.

- The drift in the structure 3 (with wall outrigger) less than in structure 2(with beam outrigger).

- The displacement in the structure 3 (with wall outrigger) less than in structure 2(with beam outrigger).

- Moment at the base of the structure 3 (with wall outrigger) less than in structure 2(with beam outrigger).

Scope for Further Study

Outriggers are a common method of stiffening and strengthening tall buildings. They work by connecting the inner core to the outer perimeter columns, when the structure is subjected to lateral forces, the outrigger and the columns resist the rotation of the core and thus significantly reduce the lateral deflection and base moment. The research program cannot solve outrigger design and construction challenges since they include a variety of situations and solutions, with new concepts being developed. Construction will always reflect location specific preferences, abilities and limitation.

Several other subjects related to this research have been identified that it needs further investigation. Experimental and analytical research works needed later are summarized below.

- Placement of outrigger and belt truss on different locations of building height. These can be placed individually or in combination.

- Type of truss outrigger can be changed and a study can be made.

- Providing outriggers in one direction and maintaining the stability by RCC

- Core in the other direction and a study can be made.

- Deep of outrigger can be increased in to two stories and a study can be made.

- Minimize force transfer by designing for similar shortening at core-and-outrigger columns through member sizing reinforcing, or material properties and a study can be made.

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